

Running Head: PRODUCTIVITY IMPROVEMENT THROUGH COMPUTER
SIMULATION

**U.S. Army - Baylor University
Graduate Program in Health Care Administration**

**Productivity Improvement through Computer Simulation: Analysis of
Staff Utilization Prior to Facility Occupation**

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A Graduate Management Project
Submitted to:

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Abstract

The Fort Monroe Health Clinic is in the process of preparing to move into a fully renovated facility. Key staff members determined they had a window of opportunity to examine and improve their clinic operations before reoccupation. The tool of computer simulation was selected to assist in that effort. The purpose of the study was to reduce patient utilization of the waiting room. This was done by projecting the status quo clinic operations into the renovated clinic (Base Model) and comparing the results against a proposed medical specialist-physician work relationship combined with an alternative location for screening patients (Alternate Model). The Base Model was designed and tested for validity before creating the Alternate Model of the staff's proposal. Both models were run through two possible scenarios involving medical specialist personnel losses. Comparison of the model outputs revealed that the Alternate Model, under both scenarios, generated lower waiting room utilization rates than those of the Base Model.

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Introduction

Conditions Which Prompted the Study

Located on the fortress-island of Fort Monroe, Virginia, and serving the Headquarters of the U.S. Army Training and Doctrine Command (TRADOC), is the Fort Monroe Health Clinic (FMHC). Supported by McDonald Army Community Hospital (MACH) at nearby Fort Eustis, the FMHC's mission is to provide primary care services to an enrolled beneficiary population of 2,425 active duty members, family members, and retirees and their family members (CHCS, October, 1997). The clinic is staffed with a variety of military personnel, federal employees, and contracted care providers -- 30 individuals in all (Uniform Chart of Accounts Personnel Report System, 1997).

The FMHC originally began service as a four story, in-patient hospital around 1898. Over the years it has evolved to its present configuration as a primary care facility under the Department of Defense's (DoD) TRICARE program. The FMHC has expanded only three times, generally by incorporating nearby existing structures. The last of these expansions occurred in 1932 (E. Waters, personal communication, September 25, 1997).

In 1995, it was determined that, while the FMHC was the appropriate size for its role as an outpatient health clinic, the facility itself was in dire need of renewal and an upgrade in equipment. The renewal construction alone was budgeted at \$4.3 million. With the added cost of upgrading the equipment, the entire project was set at \$6 million. The contract was awarded to J. Kirlin, Inc. and initial demolition began in April 1997. The project is expected to be completed in July/August 1998 (E. Waters, personal communication, September 25, 1997).

Before the renewal began, the FMHC staff and their equipment were relocated to an interconnected set of trailers in a nearby field. The beneficiary population of Fort Monroe continues to receive health care from this location.

In anticipation of the move back into the health clinic, some members of the FMHC staff began discussing how to best organize the clinic. The head nurse, in particular, recognized an opportunity to improve staff operations on the second floor. She was interested in this floor because once the renewal is completed, the second floor will become the new primary care floor. The greatest volume of patient treatment and physician interaction will occur here. (The first floor will house mostly administrative functions. Ancillary services, such as laboratory, optometry, and radiology, will be located on the third floor.) Patient treatment on the second floor will center around three primary care physicians. Each of the physicians will have an office and two exam rooms, a much different arrangement than the current one office, one exam room per physician configuration.

The head nurse wanted to know how efficient the current process of treating patients in the trailers would be once she and the rest of the staff reoccupied the primary care floor in the FMHC. She and the Clinic NCOIC (non-commissioned officer-in-charge) also wanted to know if the patient care process could be made more efficient by making changes in staffing assignments and in the patient screening process.

Statement of the Problem

The FMHC staff must determine the optimal utilization of their personnel and screening process for primary care (second floor) before reoccupying their renewed health clinic. In order to do that, the utilization of select staff members and the length of

time patients wait prior to being seen by a primary care physician have to be analyzed. By determining a performance benchmark using the current staff's mode of operations, comparisons can then be made with any proposed changes in staff utilization or screening processes.

Literature Review

In order to solve the staff's problem (or, alternatively, exploit the opportunity) presented by the facility renovation, a method was needed. Following a discussion with the head nurse on the role of computer simulation in process planning and decision making, she agreed to apply simulation modeling as a tool to assist in the FMHC primary care floor study. Although simulation may seem to be a relatively new tool for health care planners, it has actually been used for quite some time to study health care facilities and their operations. As early as 1962, simulation was used to study admissions rates in an emergency and non-emergency setting (Benneyan, 1997).

Simulation has been defined as the, "imitation of the operation of an actual process over time" (Benneyan, 1997, p. 3). Simulation seeks to recreate the logic of a process as well as the variability that may occur in such a process over a period of time. Having the ability to realistically recreate a process/system allows an evaluator to determine what affect proposed changes would have on that process/system.

Simulation lends itself readily to health care system modeling because it is a stochastic method. Specifically, a stochastic method takes into account the presence of variability or randomness in a process and incorporates that presence into the final analysis. Deterministic methods do not recognize process variability. This variability may be excused if one is analyzing a robotic assembly line where every movement is controlled

to the very second. However, in a process which is dominated by the interaction of human beings (e.g. providing health care), the lack of accountability in the variation of patient arrival times, staff shifts and breaks, queing and treatment times can produce wildly inaccurate statistical results (Benneyan, 1994).

While Dawson (1994) noted that simulation and more traditional analysis techniques may produce the same results in terms of averages, she also found it dangerous to make decisions based on those averages. Simulation produces more data, such as ranges, maximum and minimum utilization rates, etc., which, when taken as a whole, produce a much more realistic picture for decision analysis.

Mahachek (1992) elaborated further on this point by relating credibility to the ever increasing competition for resource dollars. The use of simulation provides more validity to process reengineering proposals and the resource needs tied to those proposals.

The other advantage of using simulation is that it is relatively inexpensive, and it is far less disruptive to simulate a complex system than to initiate an actual trial change for study. According to Benneyan, “ ‘Before simulation models were available, there was no way to estimate the relative size’ of the changes in waiting time and utilization due to changes in providers” (1994, p. 330). Thus, simulation offers a real advantage when analyzing a highly interactive process where patients are being routed to a variety of locations for tests and procedures.

A final advantage is the fact that simulation does not need to be run in real time in order to collect data. For many studies, it would take months, even years, to collect enough data to determine statistically significant outcomes (Benneyan, 1997).

Fortunately, most, if not all, of the available simulation software will run a program in compressed time in order to accumulate enough replications for data analysis.

Although there are some drawbacks to using simulation, they do not apply to this particular study. One commonly noted drawback is that simulation is very time intensive. However, it is not building the model but actually gathering the data necessary for input into the model that is the most time consuming. Kalton (1997, p. 60) found that, "We spent more time and effort in understanding the Breast Cancer Center operation and collecting data than in the development of the simulation model". And in a 6-month study of ambulatory admitting, only one week of the total project time was actually devoted to model building. The rest of the time was devoted to data collection and model verification (Ditch, 1997).

As the model becomes more complex, it requires additional data and continuous verification. Benneyan (1997) cited a study that observed many simulation projects take twice as long as originally planned. Fortunately, the total time forecasted for this simulation study does not appear to be a problem. At the time the initial research began, the renovated FMHC was not scheduled for occupation for approximately 10 months. This was considered ample time for completing the study. Most simulation studies show a range from 4 months (Dawson, 1994) to 6 months (Ditch, 1997) in the amount of time required to complete models of medium complexity.

Another drawback to simulation is that the software itself can be expensive. In this case, expense was not a factor because the software, MedModel® version 3.5, was on loan to the modeler under an agreement with ProModel® Corporation of Ogden, Utah.

Because the FMHC is a primary care facility, special attention was paid to simulation studies that have been successfully conducted in the past to model ambulatory care facilities and services. Some more recent examples include the simulation of an outpatient registration process (Ditch, 1997); staffing levels and the number of examination rooms needed in a family care clinic (Allen, 1997); physician utilization and patient wait times in a breast care center (Kalton, 1997); and an investigation into maximizing patient throughput in an ambulatory surgery clinic (Schroyer, 1997).

However, all four of these simulation studies (and others) were the result of a need to improve some current aspect(s) of performance in an existing health care facility. More challenging was the search for simulation studies that explored improvements or efficiencies prior to the actual occupation of a facility.

In one study conducted by Levy, Watford, and Owen (1989), Anderson Memorial Hospital of Anderson, South Carolina was examining a proposed floor design for its new Outpatient Services Center. Levy, Watford and Owen participated in the analysis of existing outpatient services utilization, and patient waiting and flow times. The purpose of their analysis was to use the data to develop a simulation model. With the model, they hoped to optimize facility size and patient wait times for the new Outpatient Services Center. This study was an invaluable reference because it demonstrated that historical data generated in an existing facility could be applied to create statistically significant outputs in the modeling of a new facility design.

A similar, but more recent, study was conducted by Allen, Balash, and Kimball (1997). In the creation of their simulation model, the patient visit data came from existing clinics. But what they were modeling was a proposed plan for a new, primary

care floor. The study was so successful that further analysis (an expansion of the model to include ancillary services on other floors) was deemed necessary and recommended to the facility staff.

Finally, Schroyer (1997) used simulation to develop a fuller understanding of ambulatory surgical processes in a medical center. The results were used as a benchmark to measure operational improvements that the staff expected in a proposed ambulatory surgical center. Based on the comparison between the modeling outputs of the existing processes and those of the proposed ambulatory surgical center, the design of the center was altered.

Purpose

The purpose of the FMHC simulation study was to reduce patient utilization of the clinic waiting room by increasing staff efficiency in the proposed primary care clinic (second floor). Specifically, the staff wanted to determine if altering the working relationship assignments of their medical specialists and the types of rooms used for screening patients would reduce patient utilization of the waiting room.

Because the architectural design for the renewal project had already been approved before this study was initiated, the physical layout of the second floor could not be considered as a factor in solving this problem.

Method and Procedures

After determining that computer simulation could be used to solve this problem, a series of steps had to be laid out and formalized to ensure efficient efforts. Past simulation studies have shown that certain steps are vital to the success of a simulation

project. The most basic steps involve preparation, model development, validation of the model, alternative development, and more validation (Krall, 1994). A better list of the general steps to take in a simulation project is the following: problem definition and project objectives; model development, data collection, and verification/validation; experimentation and analysis; presentation of findings; and implementation (Benneyan, 1997). This is the format adopted for this graduate management project.

Problem Definition and Objectives

The problem was defined as determining the best utilization of the FMHC medical specialists and the location of patient screening in primary care (second floor) in order to reduce patient utilization of the waiting room before the staff reoccupies the renewed health clinic. This problem was solved in three phases.

The first phase was to determine the benchmark, or status quo, medical specialist utilization by projecting the staff's current operations into a model of the renovated primary care floor. This constitutes the Base Model (Figure 1). (A medical specialist is an enlisted, U.S. Army member who is school trained for battlefield wound management and minor illnesses.)

At FMHC, the staff provides primary care services through three physicians. Because it is a TRICARE Prime site, the clinic sees primary care patients by scheduled appointment. However, some patients who arrive during the morning sick call hours can be seen on a first-come, first served basis. In either case, the physicians are assisted in patient screening and preparation by a pool of medical specialists. There is no long-term assignment of a medical specialist to a single physician. Instead, a available medical specialist is randomly selected to take the patient's initial information and vital signs in a

screening room (Room 226) set apart from the physician's two exam rooms. Once the physician arrives, the medical specialist returns to the "pool" near the reception desk and awaits further assignment.

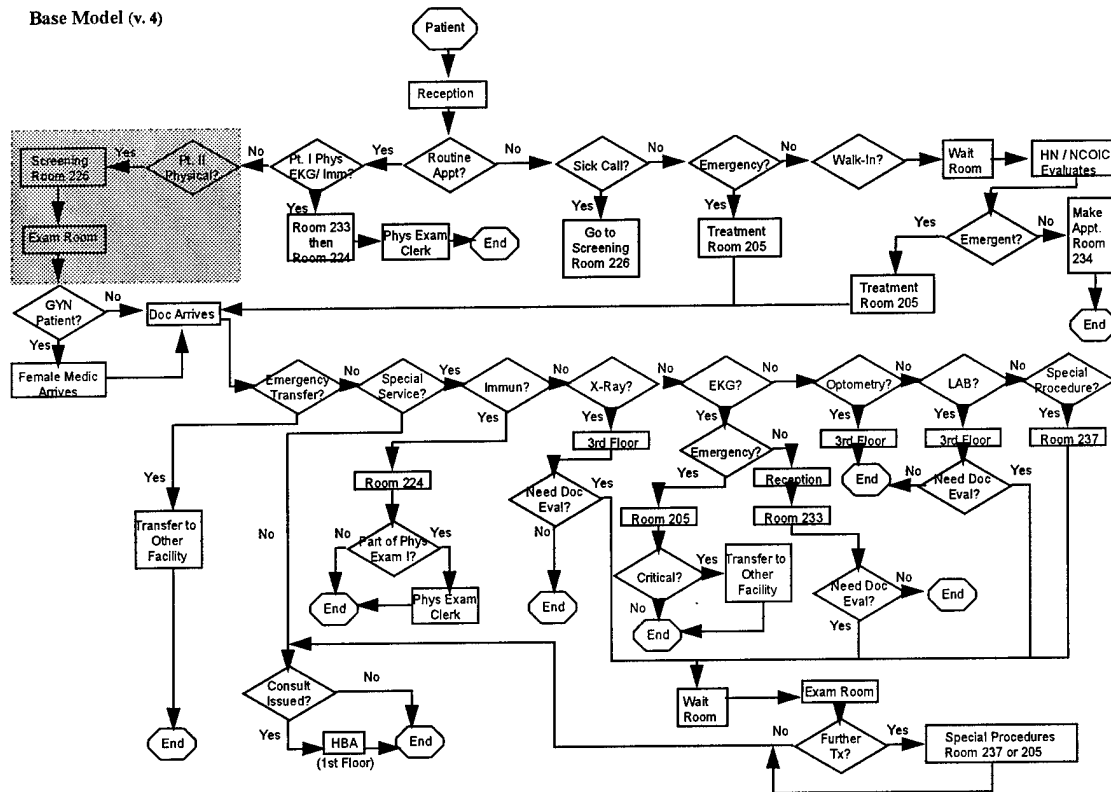


Figure 1. Base Model of proposed patient flow process, second floor, Fort Monroe Health Clinic. Physician with two exam rooms; patients screened in separate room; and medical specialist not assigned to the physician.

One assumption that was made concerned who was going to fill the role of the receptionist. Currently, one of five available medical specialists fills this position. However, the head nurse believed that the role should belong to one of the civilian medical record clerks. This could free up a medical specialist to conduct patient

screening. However, the medical record clerks were not enthused with the idea. It necessitated a change in their job description which required Civilian Personnel Advisory Center (CPAC) involvement and union review (SGT Pernell, personal communication, February 1998). Although the issue did not go away, it was decided to build both models with the fifth medical specialist as the receptionist.

The second phase was to test a change in medical specialist utilization and patient screening location for an alternate proposal. This was done by slightly modifying the Base Model to create an Alternate Model (Figure 2). This modification was a proposal by the FMHC staff to assign a single medical specialist to a physician on a regular basis. Additionally, the separate screening room is eliminated altogether. Instead, a patient is screened in one of the physician's exam rooms by the medical specialist. Once the physician arrives to conduct the exam, the medical specialist takes the next patient to the second exam room to conduct initial screening. In this manner, the physician and medical specialist work in concert using the physician's two exam rooms.

The third phase of this simulation study was to determine the most efficient process by comparing the MedModel® statistical results of the Alternate Model to those of the Base Model. The primary areas evaluated were waiting room utilization and medical specialist utilization by the patients. Waiting room utilization is defined as the percentage of time the waiting room was used by patients for that simulation run. Medical specialist utilization is defined as the percentage of time the medical specialists were engaged in escorting patients to and from rooms and screening those patients.

Alternate Model (v. 4)

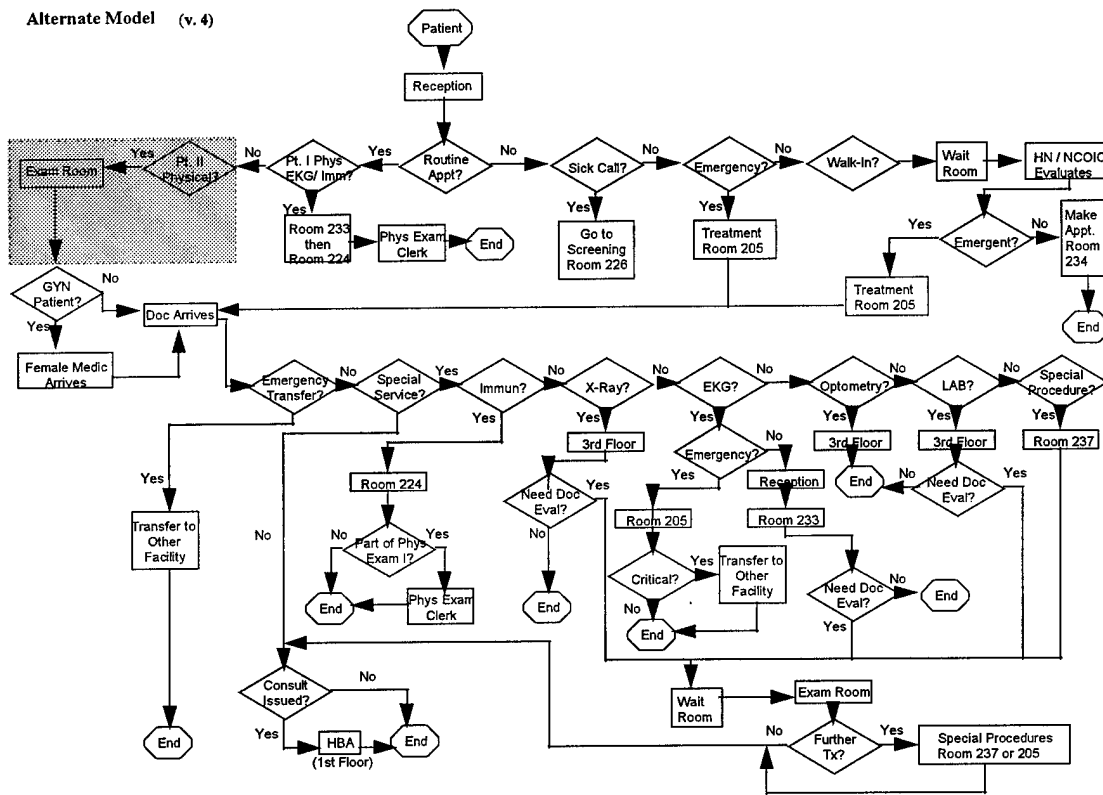


Figure 2. Alternate Model of proposed patient flow process, second floor, Fort Monroe Health Clinic. Physician with two exam rooms; patients screened in exam rooms by an assigned medical specialist.

Other areas that were examined were physician utilization rates and the number of failed arrivals during the simulation run. Physician utilization is the percentage of time the physician was engaged with a patient. Failed arrivals are the number of patients who failed to enter the clinic system because there were blockages downstream in the simulation run. This means that a patient couldn't enter the system because the reception queue got full, or the maximum capacity in the waiting room was reached, and by the time the patient could enter the clinic the simulation run ended (ProModel®, 1996).

Model Development

Mahachek (1992) and McGuire (1997) advocate charting the flow of patients through the facility first. This gives the modeler a visual representation of what occurs in the health care facility and is far easier to understand than trying to carry around a mental picture. Another positive factor in creating a flow chart is that it requires involvement from the study facility's staff. This is critical to the accuracy of the model(s) and the output of the simulation runs. Maximizing participation at this stage uncovers misunderstandings and builds consensus among the staff supervisors (Mahachek, 1992).

The initial flow charting for the Base and Alternate Models began with meetings between the head nurse and the modeler. After three versions of both models had been drafted, the clinic's military physician and non-commissioned officer in charge (NCOIC) were brought in to review them..

Involving these staff members not only increased modeling accuracy but it also cemented their interest and sense of personal stake in the simulation outcomes. Indeed, the staff noted that they had no idea their actual operations were so complex. Interest generated by this process spurred the staff members to assess the flow of ancillary services. From these discussions, there was no indication that the staff would resist any possible changes which, if found, would be beneficial to their clinic operations (Mahachek, 1995).

The head nurse realized a secondary benefit of flow charting. She saw an opportunity to convert the flow charts into an algorithm. With this algorithm, the receptionist could better understand how patients moved through the clinic and use it to answer patients' questions at the front desk (Phillips, personal communications, September 17, 1997).

After further “imagineering” with the military physician and the clinic NCOIC, the fourth and final versions of the Base and Alternate patient flow process models were created and agreed upon by all members. Figures 1 and 2 depict the final versions of both the Base and Alternate Model patient flows through the proposed primary care floor. The main operational difference between the two models is highlighted by the gray box in both figures.

The models were built using version 3.5 of the MedModel® simulation software on loan from the Health Care Systems Division of ProModel® Corporation, San Antonio, Texas. An architectural drawing of the new primary care clinic (second floor) was provided by the FMHC staff. It was scanned and imported into MedModel® as a bitmapped file. Further action was taken to scale the image and save it as a background graphic. See Appendix B for an in-model view of the clinic floor.

The next step was to gather the data necessary for input into the Base and Alternate Models. In the language of simulation, the patients were identified as “entities”, the FMHC staff members as “resources”, and the placement of rooms where interaction between entities and resources occurred as “locations”. The independent variables are known as “input” or “decision variables”. For this study, the decision variables were whether the medical specialists were randomly pulled from a “pool” or assigned to physicians as a two-person team; and the location where the patient screening process took place. The dependent variables, known as “outputs”, were the resource and location utilization rates (MedModel®, 1996). See Appendix C for an example of the final programming logic for the Alternate Model - Scenario 1.

Data Collection

Data for input into the models was collected from a variety of sources over a four-month period. In order to determine the time-related inputs for the models, it was necessary to directly observe the staff at work and time their respective activities with a stop watch. Areas of specific interest for this study included the amount of time: the receptionist takes to register patients; patients spend in the waiting room before and after being screened; the medical specialists spend screening patients; each of the three physicians spends with his or her patients; and the patients spend at ancillary services (i.e., lab, x-ray, immunization, EKG, and optometry).

Collection of the time study data took the most time of any phase of this entire project. This experience confirms the previously mentioned observations on the data collection period by Kalton (1997) and Ditch (1997). Although it would have been easier to interview the staff to determine these times, the quality of both models' output depended upon the accuracy of the input data.

After data collection was completed, 95% confidence intervals were then calculated for each timed event to produce a range which could be loaded into the simulation program. One of the advantages of MedModel® is that the program randomly assigns values within this range rather than always using the mean (Allen, 1997). This increases realism. For example, in the time it took for FMHC's medical specialists to screen patients, it was found that the confidence interval was ± 0.58 minutes about the mean of 3.42 minutes. This range was written into the processing logic and was invoked whenever the patient screening activity occurred.

The historical data were far easier to collect. The source for this type data was the Composite Health Care System (CHCS), an automated, health care information storage and retrieval system for military medical treatment facilities. This system provided reports on model inputs such as: the number of patients seen in the clinic by category (walk-in, scheduled appointment, physical exams) per month; the number of ancillary care visits and the number of walk-in's and scheduled appointments seen by each physician per month.

In order to gather a suitable sample size, a report was run on CHCS which included the actual numbers of patients seen and their categories at the present FMHC location. This report included the months of December and January 1997, and February 1998.

For this reporting period, there were a total of 2,056 patient visits to the FMHC's General Outpatient Clinic. Of this number, 86 % were primary care visits, 10 % were walk-in or sick call visits, and 4 % were physical exams. Similarly, Dr. "Y" saw 45 % of the total patients, while doctors "Z" and "X" saw 35 % and 20 %, respectively. Both the patient type and patient-to-doctor distributions were loaded into the models.

Additionally, interviews with the staff provided important information on work hours, personnel shifts and lunch breaks. At the FMHC, sick call was conducted from 0730 to 0845 hours, Monday through Friday. Primary care appointments for the three physicians began at 0900 and were scheduled every 15 minutes (or four appointments per hour per physician) until 1200 hours. At that point, the physicians took a short lunch break and primary care appointments began again at 1300 hours. This continued for the rest of the day until 1600 hours.

Confidentiality was maintained on all data throughout the study. This included not just the use of historical and time study data but also the identification of staff members and other key individuals operationally involved with the FMHC.

Verification and Validation

The next step in the simulation process called for ensuring that the developed models passed the common sense test. Specifically, this involved testing for verification and validity. Although they are often confused with each other, validity and reliability require different tests and each is important.

Verification can be simply explained as, "making sure the model runs as the analyst expects it to run" (Dawson, 1994, p. 281). The process of verification includes debugging the simulation program logic as the model is being constructed. The MedModel® program provides a method for verifying the models. Once the processing and routing logic are completed, an attempt is made to run the model. If anything is wrong, the model will stop running and indicate an error in logic at the suspected programming line. No statistical output report can be produced until the modeler finds the error and fixes the logic. Additionally, the simulation view window allows the modeler to observe the staff and patients as they move about in their virtual clinic.

However, just because the simulation model runs does not necessarily mean that it is running realistically. This is where validation comes into play, and, depending on the method employed, the simulation may require evaluation by the clinic staff. Validation is defined as making sure that the model is behaving as the staff expects it to. There are several methods for checking validity. The most simple method is to have the staff

review the animation in MedModel® to see if their simulated actions accurately portray reality (Schroyer, 1997).

Another method is to perform a Turing test. This method involves running a few replications of the model to produce output data. Then the staff is asked to examine the data but is not told that it came from the model. If the staff believes the simulation output to be real time study data gathered from their clinic, then this obviously validates that the model is reasonably realistic (Benneyan, 1994).

The use of statistics to compare the model output data against the observed, input data provides a more reliable determination of validity. Simple, descriptive statistics have been used in past studies to validate models. Figure 3 shows the descriptive statistics between the observed data and the FMHC Base Model output data on patient treatment times for Dr. "X". You will notice that the means for both samples are very close.

Using similar statistical data, Krall and Steffen (1994) compared the confidence intervals between the observed data and the output from their model. They found the confidence intervals of the two data sets to be very close and accepted their model as valid. Similarly, Ditch and Hendershott (1997) believed their model to be valid because the 95 % confidence intervals for their observed and simulated data overlapped. On the basis of this approach, the Base Model for this study was found to be valid because the 95 % confidence intervals for Dr. "X" in Table 1 were $12.24 < \mu < 17.14$ (Observed Data) and $13.34 < \mu < 15.1$ (Base Model Data).

Table 1

Treatment Time Descriptive Statistics for Dr. "X"

<i>Observed Data</i>		<i>Base Model Data</i>	
Mean	14.69	Mean	14.22
Standard Error	1.25	Standard Error	0.45
Median	12.78	Median	14.61
Mode	#N/A	Mode	12.08
Standard Deviation	7.80	Standard Deviation	3.21
Sample Variance	60.87	Sample Variance	10.29
Kurtosis	0.11	Kurtosis	8.25
Skewness	0.86	Skewness	-2.02
Range	30.22	Range	20.09
Minimum	3.03	Minimum	0
Maximum	33.25	Maximum	20.09
Sum	572.86	Sum	710.88
Count	39	Count	50
Confidence Level(95.0%)	2.53	Confidence Level(95.0%)	0.91

Note. Minutes per patient.

However, for a more precise determination, validity can be ascertained through the use of two-sample hypothesis testing. The study teams of Lowery and Martin (1992) and of Ditch and Hendershott (1997) used a single method of two-sample hypothesis testing called a T-Test. With this method, they showed that their respective simulation models were valid representations of reality. The T-Test is used for sample data less than 30 observations ($n < 30$) and compares observed data with model output to assess statistically significant differences. If there is no significant difference, the null hypothesis (where the model is valid) cannot be rejected.

In this study, a Two-Tailed Test (where the population standard deviation is unknown) was selected. The null hypothesis was that the population means for the two samples were assumed to be equal ($\mu_1 = \mu_2$). This meant that the Base Model was valid if, after testing, the null hypothesis could not be rejected. The alternative hypothesis was that the

population means were not equal ($\mu_1 \neq \mu_2$) which, if the null hypothesis was rejected, meant that the Base Model was not valid. Treatment times produced by the Base Model for one of the physicians, Dr. "Y", were compared to the same physician's observed treatment times. Because both sample sizes were greater than 30, a z score was selected for where alpha (α) is 0.05. Therefore, the region of acceptance was defined as $-1.96 < TR < 1.96$ (where TR is the test ratio). After computation, the TR was found to be 0.21, which was well within the region of acceptance. The null hypothesis that the population means for the two samples were equal could not be rejected. Therefore, the Base Model was accepted as valid.

The process of validation cannot be overemphasized. Because of this process, it was initially discovered that the TR fell outside the acceptance region. When it was repeated for the other two physicians, the same result occurred - the TR was not falling into the acceptance region. This forced the action of returning to the model and reexamining everything from input data to processing and routing logic entries. An error in the processing logic was finally discovered in which the simulation instructions were sending patients to be screened twice before being seen by a physician! After the logic was rewritten and the error eliminated, the two-tailed test was conducted once again. It produced the positive results discussed in the previous paragraph.

Testing and Experimentation

An important step in producing good output data from a model is to run the simulation enough times, or replications, to obtain statistically significant samples. While more replications in a simulation run are better, there seems to be a wide variation in the number recommended. Dawson, Ulgen, O'Connor and Sanchez (1994) collected a 14-

day run of replications in their study of an emergency room. Ditch and Hendershott (1997) decided upon 45 replications of a single day in the simulation of a new ambulatory facility. Twenty replications were deemed appropriate in Allen, Ballash and Kimball's (1997) study of a family practice clinic. In his study, Levy (1989) found a statistically representative sample was achieved by accumulating 30 days of data. Lowery (1992) advocated increasing the length of the simulation run or increasing the number of replications in the model to reduce the standard error. She found six months of output data to be acceptable. However, Mahachek (p. 76, 1992) was less helpful in his recommendation that a model should be run "many times to produce a statistically significant" outcome.

According to the Central Limit Theorem, a sample size should be greater than 30 ($n > 30$) in order for the sampling distribution to approximate the normal probability distribution (Sanders, 1995). Since this study's models were simulating discrete events, where each day that passes represents one process cycle, the Base and Alternate Models were both run for 50 replications. A single replication equaled one day during the FMHC work week (Monday through Friday).

Simulation studies are like voyages of discovery because they provide room for experimentation after model validation. Initial examination of a process may to further questions. These "what if" questions can lead a modeler in many directions. Three months into the development of this study, the FMHC staff determined there were two likely environments (or scenarios) in which they wanted to run the Base and Alternate Models. In Scenario 1, both models were run assuming all staff members were in attendance. In Scenario 2, the models were run assuming two of the medical specialists

were not available for work due to external taskings. [Historically, the clinic will lose one to three medical specialists per day, two or three times per week (SSG Pernell, personal communication, October 7, 1997).] If the clinic loses two (or more) medical specialists, the clinic cannot operate with the assigned medical specialist-to-physician work relationship and instead must revert to pooling the remaining two medical specialists among the three physicians.

Although achieving the maximum utilization from providers and medical specialists is desirable, it has been noted that a true, 100% staff utilization should never be expected. This is because in reality, people will need breaks, equipment will break down, etc. Ditch and Hendershott (1997) believed that an 80% utilization rate was about as good as one could expect. There appears to be consensus on this figure. Dawson, Ulgen, O'Connor, and Sanchez (1994) also agreed that a 100% productivity level was impossible due to breaks, downtimes, and restroom and snack breaks. They targeted an optimal staff utilization rate somewhere between 70 and 80%.

The Simulation Results

Base versus Alternate Models - Scenario 1

Once the Base Model bore up to the scrutiny of verification and validity, output data were generated by running both models in Scenarios 1 and 2 for 50 replications each. Because the output of 50 replications resulted in a report over 60 pages long (per model), the average utilization percentages for Scenario 1 are summarized on the left half of Table 2. The average utilization rate for all four medical specialists in the Base Model

was fairly robust while the average utilization for the three assigned medical specialists in the alternate model was extremely small.

Table 2

Resource Utilization Comparison Rates for Base and Alternate Models

	<i>Base Model</i>	<i>Alt. Model</i>	<i>Base Model</i>	<i>Alt. Model</i>
	<i>Scenario 1</i>	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 2</i>
Medic. Sp.	75.44%	15.62%	84.03%	28.07%
Waiting	51.67	50.15	67.79	48.84
Dr. "X"	19.50	27.39	6.59	28.42
Dr. "Y"	25.31	30.17	6.92	32.16
Dr. "Z"	66.87	76.06	17.05	76.13

With regard to the waiting room, the Base Model produced a utilization rate that, again, indicated a fair amount of activity. Although somewhat nominal, there was still a decrease in patient utilization of the waiting room in the Alternate Model.

All three physicians in the Base Model were utilized in an amount that fairly approximated the utilization distribution of the historical data from the CHCS. As seen in Table 2, the utilization of each physician increased in the Alternate Model.

The simulation runs produced a number of failed arrivals which are displayed in Table 3. Failed arrivals indicate a blockage somewhere downstream in the processing of patient entities through the model. [Blockage is created when the number of patient entities waiting to enter a queue or a service exceeds the capacity of that location. If that location's capacity becomes full and blockage does result (e.g. all 38 chairs in the waiting room are occupied), it will prevent new entities from arriving and accessing the system. These are listed in the output report as "failed arrivals" (ProModel®, 1996).] The number of failed arrivals to the clinic decreased in the Alternate Model.

Table 3

Patient Entity Arrival Failures

	<i>Base Model</i>	<i>Alt. Model</i>	<i>Base Model</i>	<i>Alt. Model</i>
	<i>Scenario 1</i>	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 2</i>
Mean Failed	18.08	13.02	33	13.3

Note. Number of individuals. This mean is derived from the arrival failure numbers for primary care, walk-in, and physical exam patients.

Base versus Alternate Models - Scenario 2

In Scenario 2, the number of medics available to work in the clinic was reduced by two. When it came to predicting what the comparison between the Base and Alternative Models would show for Scenario 2, it was believed that the Alternate Model would not surpass the medical specialist utilization rate of the Base Model. It was also believed that the waiting room utilization would also remain far below that of the Base Model.

The simulation results confirmed the assumptions. The waiting area utilization in the Alternate Model was 18.95% less than that of the Base Model. Similarly, the medical specialist utilization rate in the Alternate Model was 55.96% less than that of the Base Model.

The physician utilization rates of the Alternate Model predictably increased over the results of the same model in Scenario 1. However, the Alternate Model rates were still lower than the physician utilization rates of the Base Model. Additionally, failed arrival rates were similar to the outcome between the Base and Alternate Models in Scenario 1.

Discussion

It should be pointed out again that the FMHC staff was interested in determining what would happen if one medical specialist was assigned to work with the same physician

AND the location of the patient screening was changed from a stand-alone room to the physician's exam rooms (Alternate Model). This is an important distinction because most simulation studies evaluate one decision variable at a time to judge the effect on a single model. In this case, FMHC was looking for the combined effect of both variables operating together as a separate model. Thus, the analysis was not of each variable but the comparison of results between the Base and Alternate Models.

Scenario 1

There was an expectation that comparing the Alternate to the Base Model output would reveal a significant decrease in both the medical specialist utilization rates and the patients' utilization of the waiting room. This assumption was based on the logic that if the extra step of escorting a patient back to the waiting room after being screened (Alternate Model) were eliminated, the interaction between the patient and medical specialist would also be reduced.

The statistical report generated by MedModel® demonstrated that this assumption was true. Assigning a medical specialist to a physician (rather than randomly drawing from a pool of medical specialists), and screening patients in the exam room (rather than in a separate screening room) -- all characteristics of the Alternate Model -- did reduce the utilization rates of the medical specialists dramatically. While it has already been noted from other studies that it is desirable to approach a utilization rate of 70 to 80%, that was not the preferred state for the FMHC. In their case, the lower the medical specialist utilization rates, the better. Lower utilization rates were preferable because, as noted earlier, the number of medical specialists in the clinic varies from day to day due to external support taskings. If the medical specialists were to operate in the 70 to 80%

utilization rate range on days when all were present for duty, there would be no buffer of utilization capacity given those days when one or two medical specialists are not available due to external taskings.

Unlike the medical specialist utilization rates, there was an increase in physician utilization from the Base to the Alternate Model (Table 2). This makes sense given the Alternate Model process of screening patients in the physicians' exam rooms. By eliminating the extra step of returning patients to the waiting room in the Base Model, more time was made available for patient care in the Alternate Model. This may have had an impact on physician utilization rates.

For failed arrivals, the Alternate Model was more desirable. The number of failed arrivals indicated that the simulation runs of the Alternate Model produced fewer delays throughout the clinic than did the runs of the Base Model. (Fewer delays means the number of instances where patients were delayed in queues or in the waiting room was less compared to that of the Base Model.)

Scenario 2

The results of both models under the scenario of losing two medical specialists from the staff were hardly different from those produced by Scenario 1. Certainly the utilization rate percentages (and the numbers of failed arrivals) changed but the relationship between the values of those percentages and numbers did not.

The low level of medical specialist utilization rates experienced in the Advanced Model in Scenario 1 proved fortuitous when the same model was subjected to the staff losses in Scenario 2. While the medical specialist utilization rate increased 12.45%, it

was hardly at the same (and certainly exhausting) utilization rate that the Base Model produced. In the end, the Alternate Model was still preferable to the Base Model.

Conclusion and Recommendation

To answer the head nurse's initial question asked over eight months ago, 'Will our current process of seeing patients in the trailers work as well in the upgraded clinic?', the answer is "yes". But is it the best process to carry out patient care? That question is best answered by examining the Decision Matrix in Table 4 produced from the results of the simulation.

Table 4

Decision Matrix for FMHC Process Selection

	Waiting Room Utilization %	Medic Utilization %	Physician Utilization %	Failed Arrivals #	TOTAL SCORE
Base Model - Scenario 1	51.67 / 1	75.44 / 1	30.79 / 1	18.08 / 1	4
Alt. Model - Scenario 1	50.15 / 2	15.62 / 2	44.54 / 2	13.03 / 2	8
Base Model - Scenario 2	67.7 / 1	84.03 / 1	10.18 / 1	33 / 1	4
Alt. Model - Scenario 2	48.84 / 2	28.07 / 2	45.57 / 2	13.3 / 2	8

Note. Numbers are expressed as a percentage or number of respective category followed by its score. Scoring is on a scale where one is worst, two is best. The higher score is more desirable.

The Decision Matrix shows that, for both scenarios, the Alternate Model was more preferable. Therefore, the recommendation given to the FMHC staff was to adopt the processes found in the Alternate Model. Specifically, the staff should assign a designated medical specialist to a designated physician on a long-term basis and should conduct patient screening in the physicians' exam rooms, not separately in Room 226. The fourth

medical specialist should serve as a "float", taking care of EKGs and assisting in the screening process if patient arrivals should temporarily outstrip capacity.

The only area that needs resolution is the determination of who should serve as receptionist. As noted earlier, this simulation was conducted with the assumption that the fifth medical specialist, not the civilian medical records clerk, would continue performing that role. Currently, a FMHC staff meeting has been set to discuss this issue and come to a decision. The results of this study will play a role in the outcome of that decision. Despite the fact that the staff is concerned about the loss of medical specialists due to external taskings, this study does not support the need for a fifth medical specialist in the screening process.

This process improvement study took advantage of a unique opportunity. Most studies are conducted in response to a problem after it arises within an organization. In this case, the staff of the FMHC sought to take advantage of their preparation time to avoid that situation. By incorporating simulation in their search for a more efficient way to take care of their beneficiaries, they have embraced a proactive philosophy in optimizing the delivery of care in a newly renewed facility.

Appendix A

List of Definitions

Entities - elements such as patients or lab samples which are being measured and analyzed in a MedModel® program.

FMHC - Fort Monroe Health Clinic, Fort Monroe, Virginia.

Locations - sites inside a simulation model where an activity or interaction between an entity and resource occurs.

MACH - McDonald Army Community Hospital, Fort Eustis, Virginia.

Resources - elements such as doctors, receptionists, medics, etc. which are used by an entity in a MedModel® program.

Scheduled - a patient who has an appointment with physician through the TRICARE system.

Screening - time spent gathering vital signs, interviewing the patient for their complaint and history.

Stochastic - a method of analysis that takes into account randomness and variability of the input variables.

TRADOC - Training and Doctrine Command

TRICARE - The Department of Defense's managed health care plan for all active duty members, their family members, and retirees and their family members.

Validity - the process of ensuring that the model accurately represents the system or process being modeled. Face validity is subjective. Statistical comparison of real output with computed output is objective.

Verification - the process of ensuring that the model logic is debugged and the program runs.

Appendix C

Programming for Alternate Model - Scenario 1

Model Notes: Purpose of this model is to simulate the proposed patient care process in the FMHC. In this model there is one medical specialist assigned per physician throughout the duty day. One medical specialist is a "float" (performs EKGs and helps out when patient arrivals become dense). Patients are screened in the physicians' exam rooms.

Locations

<u>Name</u>	<u>Cap</u>	<u>Units</u>	<u>Stats</u>	<u>Rules</u>
Front_Entrance	1	1	None	Oldest
Reception_Q	5	1	Time Series	Oldest
Waiting Area	32	1	Time Series	Max (aPt_Type), By Type
DocX_Office	1	1	None	Oldest
DocZ_Office	1	1	None	Oldest
DocZ_Exam	1	2	Time Series	Max (aPt_Type), By Type, First
DocZ_Exam.1	1	1	Time Series	Max (aPt_Type), By Type
DocZ_Exam.2	1	1	Time Series	Max (aPt_Type), By Type,
DocY_Office	1	1	None	Oldest,
DocY_Exam	1	2	Time Series	Max (aPt_Type), By Type, First
DocY_Exam.1	1	1	Time Series	Max (aPt_Type), By Type,
DocY_Exam.2	1	1	Time Series	Max (aPt_Type), By Type,
Third_Floor_Pt_I_PE	1	1	Time Series	Oldest, FIFO,
Third_Floor_Optom	1	1	Time Series	Oldest,
Third_Floor_Lab	1	1	Time Series	Oldest,
Third_Floor_Xray	1	1	Time Series	Oldest,
Reception_Desk	1	1	Time Series	Oldest,
Depart_Clinic	1	1	Time Series	Oldest,
Trmt_Room_Table2	1	1	None	Oldest,
Trmt_Room_Table1	1	1	None	Oldest,
DocX_Exam	1	2	None	Oldest,
DocX_Exam.1	1	2	Time Series	Max (aPt_Type), , First
DocX_Exam.2	1	1	Time Series	Max (aPt_Type), ,
Immunization	1	1	Time Series	Oldest, , First
EKG	1	1	Time Series	Oldest, ,
Medics_Wait_Area	4	1	Time Series	Oldest, , First

Entites

<u>Name</u>	<u>Speed (fpm)</u>	<u>Stats</u>
Patient	50	Time Series
PatientWalkIn	50	Time Series
PatientPE	50	Time Series

Path Networks

<u>Name</u>	<u>Type</u>	<u>From</u>	<u>To</u>	<u>BI</u>	<u>Dist/Time</u>
Fort_Monroe_Clinic_Path	Passing	N1Entrance	N2	Bi	21.32
		N2	N1	Bi	4.56
		N1	N3	Bi	6.32
		N3	N4	Bi	42.2
		N4	N5	Bi	6.84
		N5	N6Up	Bi	11.6
		N6Up	N7Dn	Bi	4.40
		N7Dn	N8Exit		8.68
		N6Up	N6	Bi	10.72
		N6	N7	Bi	8.52
		N7	N8	Bi	11.72
		N8	N9PE	Bi	0.60
		N9PE	N10Optom		1.96
		N10Optom	N11Lab		2.00
		N11Lab	N12XRAY		2.20
		N1	N9RecpQue		10.20
		N9RecpQue	N9	Bi	11.80
		N9	N10WaitRm		3.56
		N9	N10	Bi	8.92
		(Continues for 57 more lines!)			

Interfaces

<u>Net</u>	<u>Node</u>	<u>Location</u>
Fort_Monroe_Clinic_Path	N1Entrance	Front_Entrance
	N9Reception_Que	Reception_Q
	N10WaitRoom	Waiting_Area
	N11Reception	Reception_Desk
	N44DocX_Office	DocX_Office
	N39Zexam1	DocZ_Exam
	N38Z_Office	DocZ_Office
	N38Y_Office	DocY_Office
	N36Yexam1	DocY_Exam
	N27Trmt_Rm_1	Trmt_Room_Table1
	N26Trmt_Rm_2	Trmt_Room_Table2
	N10Optom	Third_Floor_Optomtry
	N11Lab	Third_Floor_Lab

Interfaces (Cont'd)

N12Xray	Third_Floor_Xray
N9PE	Third_Floor_Pt_I_PE
N8Exit	Depart_Clinic
N30Xexam1_Table	DocX_Exam
N24IMMUN	Immunization
N22EKG	EKG
N45Medic_Wait_Are	Medics_Wait_Area

Resources

<u>Name</u>	<u>Units</u>	<u>Stats</u>	<u>Res Search</u>	<u>Ent Search</u>	<u>Path</u>	<u>Motion</u>
Dr_X fpm	1	Sumry	Closest	Oldest	Fort M Path	Empty: 60
					Home: N44X	Full: 50 fpm
Dr_Y fpm	1	Sumry	Closest	Oldest	Fort M Path	Empty: 60
					Home: N38Y	Full: 50 fpm
Dr_Z fpm	1	Sumry	Closest	Oldest	Fort M Path	Empty: 60
					Home: N38Z	Full: 50 fpm
Xmedic fpm	1	Sumry	Idle	Oldest	Fort M Path	Empty: 60
					Home: N45M	Full: 50 fpm
Receptionist fpm	1	None	Closest	Oldest	Fort M Path	Empty: 60
					Home: N11Rc	Full: 50 fpm
Record_Cks fpm	2	None	Least Used	Oldest	Fort M Path	Empty: 60
					Home: N45Rc	Full: 50 fpm
SGT_1	1	None	Least Used	Oldest		Empty:
						Full:
SGT_2 fpm	1	None	Closest	Oldest	Fort M Path	Empty: 60
					Home: N24Im	Full: 50 fpm
Zmedic 60 fpm	1	Sumry	Least Used	Oldest	Fort M Path	Empty:
					Home: N45M	Full: 50 fpm
Ymedic fpm	1	Sumry	Closest	Oldest	Fort M Path	Empty: 60
					Home: N45M	Full: 50 fpm
FloatMedic fpm	1	Sumry	Least Used	Oldest	Fort M Path	Empty: 60
					Home: N45M	Full: 50 fpm

Clock Downtimes for Resources

<u>Resource</u>	<u>Frequency</u>	<u>1st Time</u>	<u>Priority</u>	<u>Scheduled</u>	<u>Node</u>	<u>Disable</u>	<u>Logic</u>
Dr_X	24 Hr	4.5 Hr	99	Yes	N44X_Off	No	WAIT N(60,1,
	24 Hr	7.5 Hr	99	Yes	N44X_Off	No	WAIT N(60,1,
Dr_Y	24 Hr	4.5 Hr	99	Yes	N38Y_Off	No	WAIT N(60,1,
	24 Hr	7.5 Hr	99	Yes	N38Y_Off	No	WAIT N(60,1,
Dr_Z	24 Hr	4.5 Hr	99	Yes	N38Z_Off	No	WAIT N(60,1,
	24 Hr	7.5 Hr	99	Yes	N38Z_Off	No	WAIT N(60,1,
Receptionist	24 Hr	4.5 Hr	99	Yes		No	WAIT N(60,1,

Processing

<u>Entity</u>	<u>Location</u>	<u>Operation</u>	<u>Blk</u>	<u>Output</u>	<u>Destination</u>	<u>Routing</u>
ALL	Front_Entr	INC vPt_Clinic_Integer aPt_Type=PtType_Distribution() aPt_Assignment=Pt_to_Doc_Distribution() Graphic 1				
			1	ALL	Reception_Q	First 1
ALL	Reception_Q		1	ALL	Reception_Desk	First 1
ALL	Recept_Desk	WAIT N(.57,1.92,1) IF aPt_Type=3 THEN Route 3 ELSE IF aPt_Type=2 THEN Route 2 ELSE IF aPt_Type=1 THEN Route 1				
			1	Patient	Waiting_Area	First 1
			2	PtWalkIn	Waiting Area	First 1
			3	PtPE	Third_Floor_Pt	First 1
Patient Waiting-Area	Graphic 2	WAIT N(6.15,1.05,3) IF aPt_Assignment=1 THEN Route 1 ELSE IF aPt_Assignment=2 THEN Route 2 ELSE IF aPt_Assignment=3 THEN Route 3				
			1	Patient	X_Exam	First 1
			2	Patient	Z_Exam	First 1
			3	Patient	Y_Exam	First 1

Patient X_Exam	GRAPHIC 2			
	WAIT N(3.42,.58,4)			
	FREE Xmedic			
	GRAPHIC 1			
	GET Dr_X			
	GRAPHIC 3			
	WAIT N(15.27, 2.69,7)			
	GRAPHIC 1			
	FREE Dr_X	1	Patient	Depart_Clinic First 1
PtPE Third_FlrPE	WAIT N(10,2,10)	1	PatPE	Third_Floor_Optom First 1
PtWlk Wait_Area	GRAPHIC 2			
	WAIT N(6.15,1.05,3)			
	IF aPt_Assignment=1 THEN Route 1			
	ELSE			
	IF aPt_Assignment=2 THEN Route 2			
	ELSE Route 3	1	PtWalk	X_Exam First 1
		2	PtWalk	Z_Room First 1
		3	PtWalk	Y_Room First 1
PtWalkX_Exam	GRAPHIC 2			
	WAIT N(3.42,.58,4)			
	FREE Xmedic			
	GRAPHIC 1			
	GET Dr_X			
	GRAPHIC 3			
	WAIT N(12.77,8.77,12)			
	GRAPHIC 1			
	FREE Dr_X	1	PtWalk	Depart_Clinic First 1
Patient Z_Exam	GRAPHIC 2			
	WAIT N(3.42,.58,4)			
	FREE Zmedic			
	GRAPHIC 1			
	GET Dr_Z			
	GRAPHIC 3			
	WAIT N(19.68,6.8,13)			
	GRAPHIC 1			
	FREE Dr_Z	1	Patient	Depart_Clinic First 1
Patient Y_Exam	GRAPHIC 2			
	WAIT N(3.2,.58.2,4)			
	FREE Ymedic			
	GRAPHIC 1			
	GET Dr_Y			
	GRAPHIC 3			
	WAIT N(10.47,3.2,14)			
	GRAPHIC 1			

	FREE Dr_Y	1	Patient	Depart_Clinic	First 1
PtWalkZ_Exam	GRAPHIC 2				
	WAIT N(3.42,.58,4)				
	FREE Zmedic				
	GRAPHIC 1				
	GET Dr_Z				
	GRAPHIC 3				
	WAIT N(26.17,18.13,15)				
	GRAPHIC 1				
	FREE Dr_Z	1	Patient	Depart_Clinic	First 1
ALL	Depart_Clinic DEC vPt_in_Clinic_Integer	1	ALL	EXIT	First 1
PtPE	T_F_Optom	WAIT N(4.23,3.33,15)			
		1	PtPE	Third_Floor_Lab	First 1
PtPE	T_F_Lab	WAIT N(8,1.5,17)	1	PtPE	Third_Floor_Xray
PtPE	T_F_Xray	WAIT N(4.09,1.44,18)			First 1
		1	PtPE	EKG	First 1
PtPE	EKG	GET FLOATMedic			
		GRAPHIC 2			
		WAIT N(4.23,3.33,18)			
		FREE FLOATMedic			
		GRAPHIC 1	1	PtPE	Immunization
PtPE	Immunization	GRAPHIC 2			First 1
		WAIT N(4.5,1,19)			
		GRAPHIC 1	1	PtPE	Third_Floor_Pt_I_PE
PtPE	T_F_Pt_I_PE	WAIT N(5,1,20)	1	PtPE	Depart_Clinic
					First 1

Arrivals

<u>Entity</u>	<u>Location</u>	<u>Qty Each</u>	<u>1st Time</u>	<u>Occurences</u>	<u>Freq</u>	<u>Logic</u>
Patient	Front_Entr	1;PtPrime_Cycle		1		
PatWalkIn	Front_Entr	1;SickCallPt_Cycle		1		
PatientPE	Front_Entr	1;PEPatient_Cycle		1		

Shift Assignments

<u>Locations</u>	<u>Resources</u>	<u>Shift Files</u>	<u>Priorities</u>	<u>Disable</u>	<u>Logic</u>
Frnt_Entrance	Dr_X	C:\PgrmFile\mm3\mdl	99,99,99	No	
EKG	Dr_Z				
Immun	Dr_Y				
X_Exam	Xmedic				
X_Exam.1	Receptionist				
X_Exam.2					
X_Office					
Z_Exam					
Z_Exam.1					

Z_Exam.2
 Z_Office
 Y_Exam
 Y_Exam.1
 Y_Exam.2
 Y_Office
 Reception_Desk
 Reception_Q
 Third_Floor_Lab
 Third_Floor_Optom
 Third_Floor_Pt_I_PE
 Third_Floor_Xray

Attributes

<u>ID</u>	<u>Type</u>	<u>Classification</u>
#Prime, PE, or Walk-In		
aPt_Type	Integer	Entity
#X, Y, Z		
aPt_Assignment	Integer	Entity

Variables

<u>ID</u>	<u>Type</u>	<u>Initial Value</u>	<u>Stats</u>
vPt_in_Clinic_Integer	Integer	0	Time Series

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13. ABSTRACT (Maximum 200 words) The Fort Monroe Health Clinic is in the process of preparing to move into a fully renovated facility. Key staff members determined they had a window of opportunity to examine and improve their clinic operations before reoccupation. The tool of computer simulation was selected to assist in that effort. The purpose of the study was to reduce patient utilization of the waiting room. This was done by projecting the status quo clinic operations into the renovated clinic (Base Model) and comparing the results against a proposed medical specialist-physician work relationship combined with an alternative location for screening patients (Alternate Model). The Base Model was designed and tested for validity before creating the Alternate Model of the staff's proposal. Both models were run through two possible scenarios involving medical specialist personnel losses. Comparison of the model outputs revealed that the Alternate Model, under both scenarios, generated lower waiting room utilization rates than those of the Base Model.				
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